SEISMIC ANALYSIS OF STEEL FRAME WITH BRACINGS USING RESPONSE SPECTRUM METHOD

[1]Ankit Vishwakarma, [2]Anjali Rai
[1] PG Student (M.Tech Structural Engineering), [2]Assistant Professor
[1][2] Structural Engineering, Department of Civil Engineering, Institute of Engineering & Technology, Lucknow

Abstract: ***In the construction industry steel structures played an important role in providing the strength, stability and ductility against seismic forces. It is necessary to design a structure to perform well under seismic loads. In the present study, modeling of the steel braced structures with a different combination of bracings and analysis of structure using ETAB software are done. A bracing element in the structural system plays a vital role in structural behaviour during an earthquake. In this study two types of bracings are used X and V bracings in Zone III and analysis is carried out by Response Spectrum Method. Various parameters are considered such as Natural Time period, Base shear, Storey displacement and Storey stiffness were studied. From this study it is concluded that, X-bracing are the best bracing system for reducing the storey displacement. It is also observed that base shear is high in X-bracing system because of the increased stiffness. In this work Comparison between the seismic parameters such as Natural Time period, base shear, storey displacement and Storey stiffness for steel frame with different combination of bracing and without bracing are studied.***

Index Term: ***Steel Frame Structure, ETAB Software, X-Bracing, V-bracing, Natural Time period, Base shear, Storey Displacement, Storey stiffness.***

I INTRODUCTION

Steel structure must have adequate strength and stiffness so that storey displacement is controlled in order to prevent damage to structural and non structural elements. A steel frame can be strengthened in various types to resist lateral forces. The structural system used to resist lateral loads is bracing. These systems are moment resisting beam-column connections; braced frames with moment-resisting connections, braced frames with pin jointed connections and braced frames with both pin-jointed and moment-resisting connections. A bracing element in the structural system plays a vital role in structural behaviour during an earthquake. Steel bracing is an effective and economical solution for resisting lateral forces in a framed structure..Most widely used lateral load resisting system is bracing. Diagonal structural element is inserted in structural system so that triangulation is formed. It is strong in compression. Bracing system is economical and Selection of appropriate lateral load resisting system has significant effect on performance of steel frame structure. Steel bracing is economical, easy to erect and occupies less space. There are two types of bracing systems, Concentric Bracing System and Eccentric Bracing System
Bracing systems are mainly categorized into two systems:

1. **Concentric Brace system**: Concentrically brace frames CBF consisting of columns, beams, trusses joined with pin connection. Lateral load in this system is resisted by truss action and columns. CBF have high stiffness as braces are in compression and may buckle which is brittle failure.

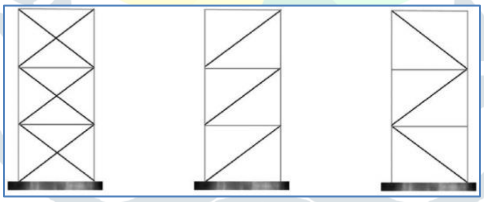


Fig.1: X-Bracing   Fig.2: Single bay of Diagonal Bracing

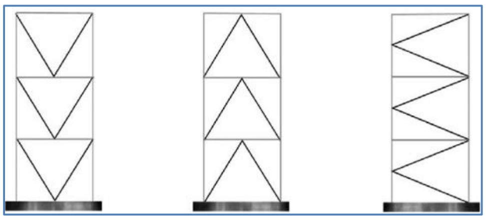


Fig.3: V-Bracing, Inverted V-Bracing, K Bracing

2. **Eccentric Brace system:** It is relatively new lateral force resisting system developed to resist seismic events in a predictable manner. Properly designed and detailed EBFs behave in a ductile manner through shear or flexural yielding of a link element. Figure shows below:

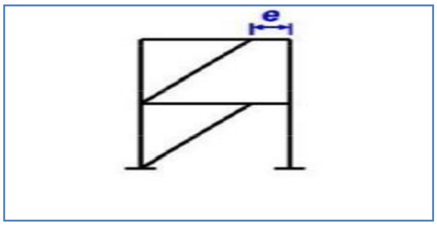


Fig.4: Eccentric Brace frame

II OBJECTIVE OF STUDIES

The aim of this research is analysis of steel frame building with different Bracing system under gravity and seismic load.

1. To study the performance of steel frame building with different arrangement of bracing and without bracing systems.
2. To compare the parameters such as, Natural time period, Base shear, storey displacements, stiffness on the performance of Multi storey buildings with different types of bracings i.e., (X and V).
3. To find optimized bracing system under given loads.

III METHOD OF ANALYSIS

Response Spectrum Method: Response spectra are curves plotted between maximum response of SDOF system subjected to specified earthquake ground motion and its time period (or frequency). The maximum response is plotted against the undamped natural period and for various damping values and can be notified in terms of maximum relative velocity or else maximum relative displacement.

1. Natural Period: Natural Period T_n of a building is the time taken by it to undergo one complete cycle of oscillation. It is an inherent property of a building controlled by its mass m and stiffness k. These three quantities are related by:

$$T_n = 2\Pi\sqrt{(m/k)}$$

It's units are seconds (s).

2. Base shear: The design base shear along any principal direction of a building shall be designed by:

$$\mathbf{V_b = A_h \times W}$$

$$\mathbf{A_h = \frac{\left(\frac{Z}{2}\right)\left(\frac{Sa}{g}\right)}{\left(\frac{R}{I}\right)}}$$

3. Storey Displacement: According to **EURO CODE,** allowable displacement is calculated as **H/250**, Where H is total height of building above the ground level in millimetres (mm).

IV STRUCTURAL BUILDING DETAIL

The length and width of the building are 22.5m and 22.5m. The height of storey is 3m. The building is symmetrical to X and Y axis. The columns are assumed to be fixed at ground level. In this study, A G+19 storey steel building of 5 bays in X-direction and 5 bay in Y- direction have been considered for the investigation the effect of the different types of bracing. Below table shows details of the building that is used for the analysis of the building. Some identical steel section is used for all bracing pattern. The building has been analyzed using commercially available ETAB software.

Table 1: Description of the Building

S.No	Structural Part	Dimension
1.	Location	Lucknow (U.P)
2.	Type of Building	Residential Building (G+19)
3.	Plan Dimension	(22.5m×22.5m) =506.25 sq.m
4.	Type of structure	Steel structure
5.	Length in X-direction	22.5m
6.	Length in Y-direction	22.5m
7.	No of bays in X-direction	5No@4.5m
8.	No of bays in Y-directions	5No@4.5m
9.	Floor to floor height	3m

10.	Total height of building	60m
11.	Slab thickness	127mm
12.	Column size	ISMB 600
13.	Beam size	ISMB 450
14.	Secondary Beam for slab	ISMB 400
15.	X-Bracing	ISMB 350
16.	V-Bracing	ISMB 350

Table 2: Material Properties

S. No	Material	Grade
1.	Grade of steel	Fe250
2.	Rebar	HYSD 500
3.	Density of steel	7850 Kg/m3
4.	Young's Modulus E	$2.1 \times 10^5 N/mm^2$
5.	Shear Modulus	80000 N/mm^2
6.	Poisson's Ratio	0.3
7.	Concrete	M30

Table 3: SEISMIC DATA: As Per IS 1893:2016 (part 1)

1.	Earthquake Zone	III
2.	Zone Factor	Z = 0.16 (clause 6.4.2)
3.	Damping Ratio	5%
4.	Importance Factor	1.2 (clause 7.2.3)
5.	Type of soil	Medium soil (clause 6.4.2.1)
6.	Response Reduction Factor	5 (SMRF) (clause 7.2.6)

LOADINGS:

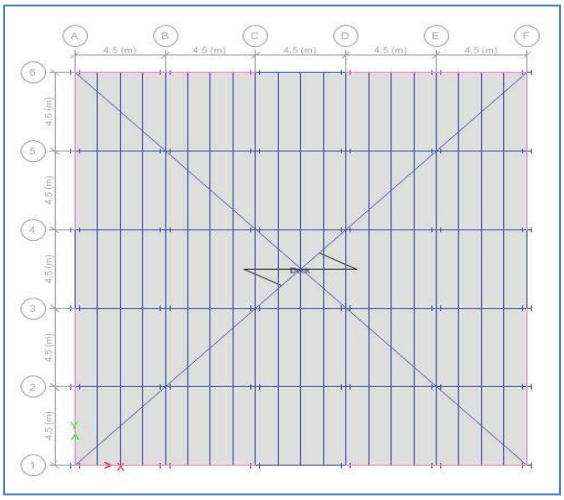
a) Live load 2 KN/m^2 as per IS 875 Part II
b) Dead Load of Building as per IS: 875- Part (I)
c) Earthquake load as per IS 1893:2016 Part (I)

V PROBLEM FORMULATION

Here we have considered the steel structure multi-storey building with different types of bracings subjected to under seismic loading as per IS 1893:2016 code provision. Seismic analysis of steel frame building with different bracings and without bracing system is carry out by using ETAB software.

- Model 1 -Steel Frame Building (G+19) without Bracing
- Model 2 -Steel Frame Building (G+19) with X-Bracing.
- Model 3 -Steel Frame Building (G+19) with V-Bracing.

Model 1: Steel Frame Building (G+19) with Without Bracing



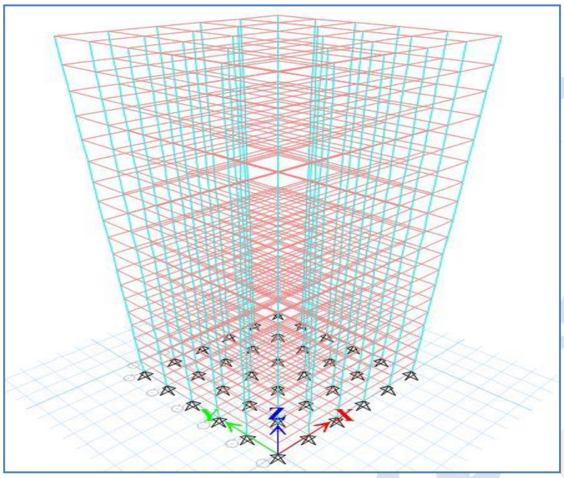
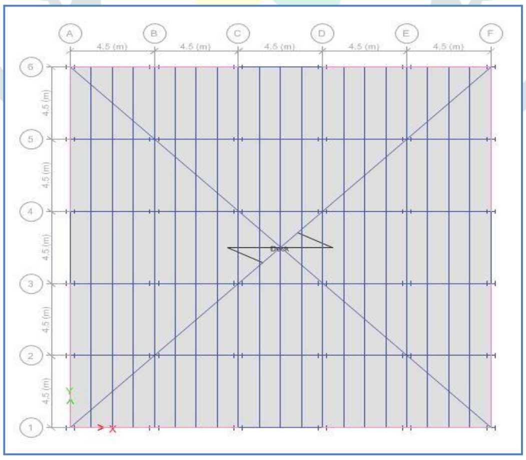


Figure 5: Plan and 3-D view

Model 2: Steel Frame Building (G+19) with X-Bracing



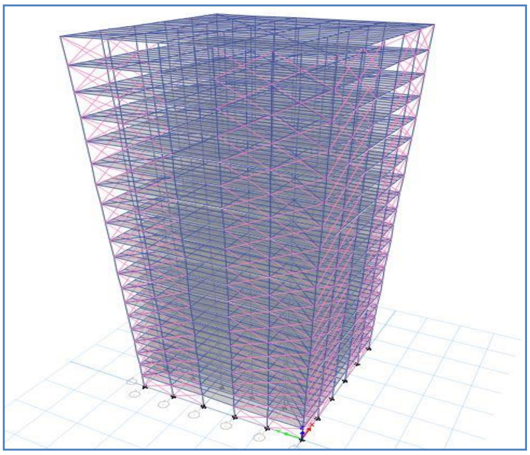
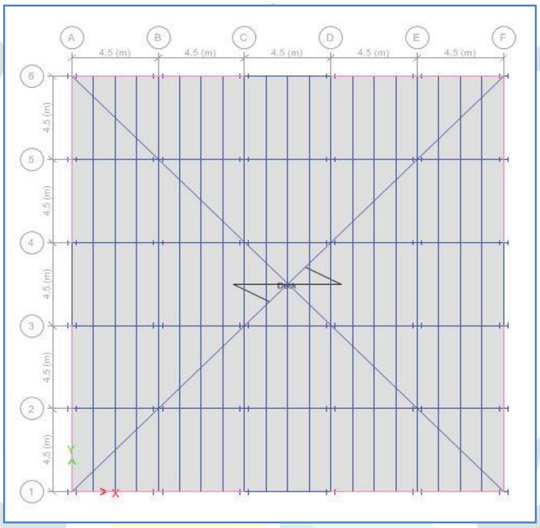


Figure 6: Plan and 3-D view

Model 3: Steel Frame Building (G+19) with V-Bracing.



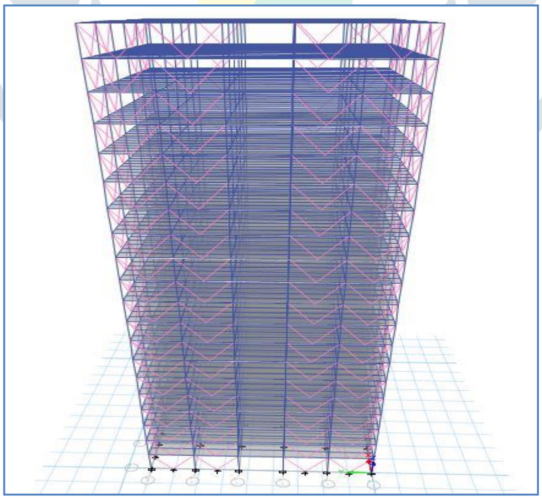


Figure 7: Plan and 3-D view

VI RESULT AND DISCUSSION

The parametric study of Natural Time period storey displacement and storey stiffness of building in different stories by response spectrum analysis for (G+19) storeys is performed here. The results obtained from the analysis are compared by graphical representation:

A. Natural Time Period

Table 4: Natural Time Period

Mode	Without Bracing (sec)	V-Bracing (sec)	X-Bracing (sec)
Mode 1	8.407	2.803	2.669
Mode 2	4.059	2.414	2.303
Mode 3	3.65	1.349	1.264
Mode 4	2.799	0.78	0.717
Mode 5	1.662	0.687	0.641
Mode 6	1.329	0.405	0.37
Mode 7	1.189	0.387	0.349
Mode 8	1.182	0.345	0.318
Mode 9	0.927	0.254	0.227
Mode 10	0.765	0.228	0.208
Mode 11	0.762	0.212	0.191
Mode 12	0.667	0.189	0.167

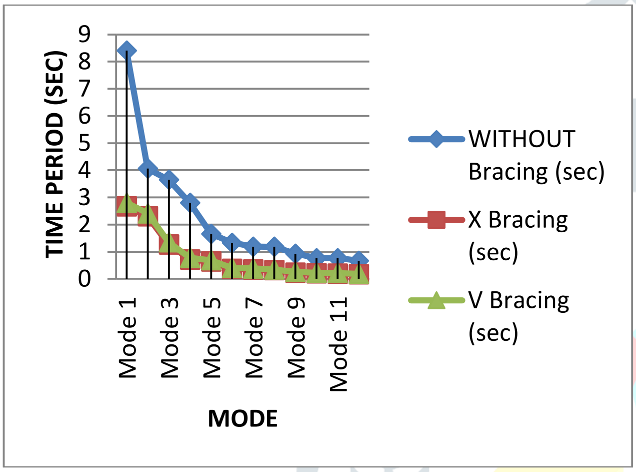


Figure 8: Comparison of Time period

From above graph and table of Natural time period, it is concluded that X-bracing is more efficient bracing as compared to without and V-bracing systems.

B. Comparison of Base Shear

Table 5: Base Shear

BRACING TYPE	BASE SHEAR V_B (kN)
WITHOUT BRACING	1051.6747
X-BRACING	1694.5342
V-BRACING	1610.5416

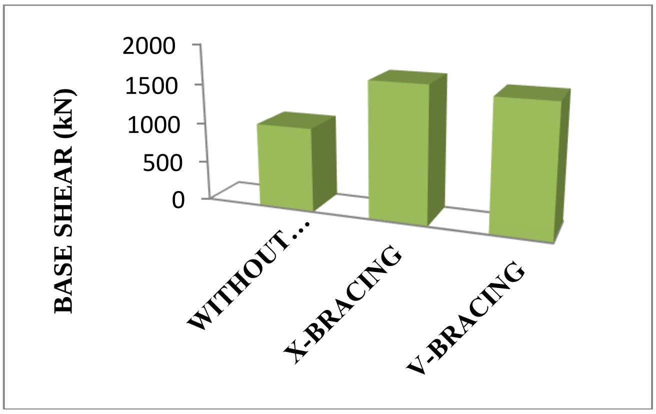


Figure 9: Comparison of Base Shear

From above graph and table of Base shear, it is concluded that X-bracing is more efficient bracing as compared to without and V-bracing systems.

C. Storey Displacement

Table 6: Storey Displacement

Storey	Without Bracing (mm)	V-Bracing (mm)	X-Bracing (mm)	As per Code H/250 (mm)
Storey 20	316.536	61.672	59.857	240
Storey 19	312.637	58.743	56.877	228
Storey 18	306.294	55.682	53.774	216
Storey 17	297.737	52.491	50.55	204
Storey 16	287.208	49.176	47.212	192
Storey 15	274.936	45.75	43.772	180
Storey 14	261.137	42.23	40.248	168
Storey 13	246.015	38.637	36.664	156
Storey 12	229.762	34.997	33.044	144
Storey 11	212.556	31.338	29.243	132
Storey 10	194.563	27.688	25.819	120
Storey 9	175.935	24.081	22.278	108
Storey 8	156.811	20.551	18.833	96
Storey 7	137.318	17.135	15.523	84
Storey 6	117.569	13.857	12.328	72
Storey 5	97.664	10.796	9.471	60
Storey 4	77.689	7.959	6.82	48
Storey 3	57.718	5.405	4.486	36
Storey 2	37.812	3.187	2.527	24
Storey 1	18.032	1.362	1.005	12

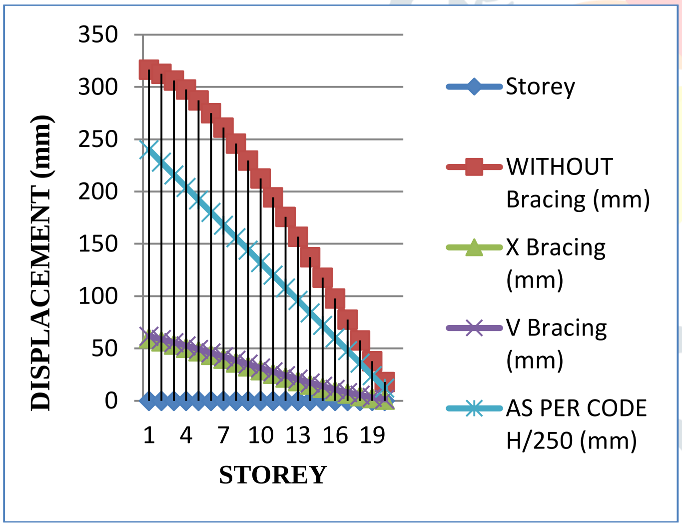


Figure 10: Comparison of Storey Displacement

From above graph and table of Storey displacement, it is concluded that X-bracing is more efficient bracing as compared to without and V-bracing systems.

D. Storey Stiffness

Table 7: Storey Stiffness

Storey	Without Bracing (kN/m)	V-Bracing (kN/m)	X-Bracing (kN/m)
Storey 1	828576.163	2477532.396	3191677.443
Storey 2	462378.906	1659305.432	2061121.023
Storey 3	406630.113	1414913.815	1688036.992
Storey 4	387360.193	1239212.677	1439970.165
Storey 5	376428.412	1105159.077	1260570.506
Storey 6	368355.619	999388.755	1123203.57
Storey 7	361994.549	913950.113	1014183.816
Storey 8	356705.306	843860.913	925949.795
Storey 9	351629.836	787029.09	855403.849
Storey 10	345981.169	743100.974	801898.526
Storey 11	339494.136	711032.003	764097.437
Storey 12	332681.87	687700.176	738131.177
Storey 13	326679.101	669000.927	718744.046
Storey 14	322475.621	651711.788	701523.417
Storey 15	319888.488	633459.404	683104.101
Storey 16	317147.563	610332.852	658750.503
Storey 17	311132.897	574179.776	619486.984
Storey 18	296886.937	511753.324	551146.54
Storey 19	263948.866	406020.643	435689.365
Storey 20	182980.19	241717.614	257681.469

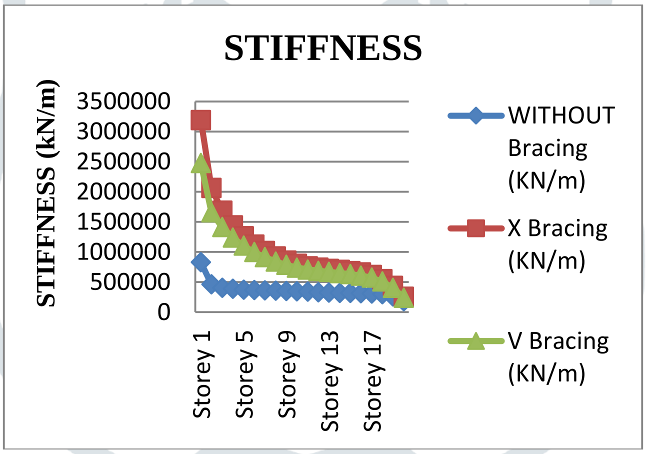


Figure 11: Comparison of Storey Stiffness

From above graph and table of Storey stiffness, it is concluded that X-bracing is more efficient bracing as compared to without and V-bracing systems.

VII CONCLUSIONS

From the above work the following conclusion are given below:

1. Natural Time period

i. From above **graph 8** and **table 4** it is concluded that X-bracing is 65.603% efficient as compared to without bracing systems model.
ii. From above **graph 8** and **table 4** it is concluded that X-bracing is 6.256% efficient as compared to V- bracing systems model.

2. Base shear

i. From above **graph 9** and **table 5** it is concluded that X-bracing is 37.93% efficient as compared to without bracing systems model.
ii. From above **graph 9** and **table 5** it is concluded that X-bracing is 4.95% efficient as compared to V- bracing systems model.

3. Storey Displacement

i. From above **graph 10** and **table 6** it is concluded that X-bracing is 85% efficient as compared to without bracing systems model.
ii. From above **graph 10** and **table 6** it is concluded that X-bracing is 5.37% efficient as compared to V- bracing systems model.

4. Storey Stiffness

i. From above **graph 11** and **table 7** it is concluded that X-bracing is 64.57% efficient as compared to without bracing systems model.
ii. From above **graph 11** and **table 7** it is concluded that X-bracing is 12.737% efficient as compared to V- bracing systems model.

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